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IV. "On the Serpentine of Canada and their associated Rocks."

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The origin and formation of serpentine is still regarded as an unsettled problem by chemical geologists, and Sir William Logan having shown from structural evidence the undoubted stratified character and sedimentary origin of the serpentine of the Green Mountains in Canada, I have been induced to make a chemical and mineralogical investigation of these serpentines and the rocks associated with them. In the present note I propose to indicate briefly some of the results obtained, reserving for another occasion the details of my examination.

The serpentines of the Green Mountains, which have been traced for 150 miles in Canada, have been found by Sir William to belong to the upper portion of the Lower Silurian system, whose disturbance and metamorphism have given rise to the great Apalachian chain, of which the Green Mountains are the north-eastern prolongation. These mountains are composed of gneissoid, micaceous, argillaceous, talcose, and chloritic schists, with quartzite, limestone, dolomite, serpentine, pyroxenite, and the other rocks about to be mentioned.

The serpentines, which form immense beds, and often cover large areas, are sometimes homogeneous, and at other times conglomerate in their character, the cement being a ferruginous dolomite, or more rarely a carbonate of magnesia, exempt from lime but containing carbonate of iron. In some cases the serpentine is intimately mixed with a large amount of carbonate of lime. Chromic and magnetic iron, ilmenite, diallage, with the ordinary lamellar and fibrous varieties, picrolite and chrysotile, are common in these serpentine rocks. The results of a great number of analyses show a uniformity of composition in all the serpentines of this formation, and also show a curious fact hitherto overlooked,—that of the constant presence of a small portion of nickel, never exceeding a few thousandths. I have never failed to detect it in any variety of serpentine from this formation, not only in Canada, but in the States of Vermont, Connecticut, and New Jersey. Its presence seems still more widely spread, for I have also found nickel in serpentines from California, the Vosges in

France, and in a *verd antique* marble from a Roman ruin. The association of nickel with the chromic iron and serpentines of Pennsylvania has been long known, and I have found the chromic iron of Canada to contain small portions both of nickel and cobalt, although the latter metal can rarely be detected in the nickeliferous serpentines.

The results of a number of analyses show that it is constantly present in the talcose slates and steatites of this region, and the same is to be observed of the magnesites and dolomites of the series; indeed the distribution of nickel would seem to be co-extensive with that of the magnesia in this formation, and the same thing may be said of chrome. I have not, however, met with any traces of chrome or nickel in the serpentines and talcose rocks of the Laurentian system, which underlies the Silurian and the still older copper-bearing rocks of Lake Huron, and probably corresponds to the oldest gneiss of Scandinavia. Both chrome and nickel, however, characterize the serpentines of the Vosges and of California. I have not yet been able to examine specimens from other foreign localities. The presence of traces of nickel in certain talcs was long since noticed by Stromeyer. Much of the so-called talcose slate of the Green Mountains is not magnesian, but consists of a hydrous aluminous silicate allied to pyrophyllite or pholerite, which are alumina-talcs.

The euphotides, which are associated with many of the European serpentines, are not wanting in the Green Mountains, although less distinctly marked to the eye than the foreign varieties. A tough, greenish or greyish-white rock, with a waxy lustre, forms in many places great stratified masses, which are associated with the serpentine, and is found on analysis to consist of a soda-felspar (albite) with a silicate of lime, magnesia, and protoxide of iron, having the composition of amphibole,—thus constituting a veritable euphotide. The two minerals are clearly distinguishable after calcination, which blanches the felspar, and reddens the ferruginous silicate. These rocks are by this means distinguished from others similar in their appearance and mode of occurrence, but consisting of petrosilex or compact siliceous felspar, and equally members of the sedimentary series. The specific gravity of these euphotides shows that the saussurite or felspar which forms their base has a density not greater than that of ordinary soda-felspar.

Immediately connected with the serpentines, there sometimes occurs a white compact rock, remarkable by its great hardness, and a density of 3·3 to 3·5. Analysis shows this rock to be a pure lime-alumina garnet, in some cases, however, mingled with another silicate which appears to belong to the amphiboles. This garnet is sometimes blended with serpentine, and at others forms distinct beds. In its general aspect it resembles closely the saussurite of the associated euphotides, and has probably often been confounded with that mineral by previous observers. Hence the densities of 3·2 and 3·3 assigned by different mineralogists to the saussurites of the Alps, while Delesse has shown that the true saussurite of the euphotide of Mount Genève, like that of the Vosges, is a felspar.

The magnesites of this region form great beds; they are crystalline, and consist of carbonate of magnesia with some carbonate of iron, and contain as imbedded minerals in some cases grains of quartz, in others felspar and talc, and at other times serpentine, but always holding chrome and nickel, the latter as a greenish carbonate, in the joints of the rock, or in the form of nickeliferous pyrites.

These magnesian rocks are not confined to the altered portions of this formation; beds of siliceous dolomite holding protocarbonate of iron are found, interstratified with pure fossiliferous limestones, near Quebec. The reaction between silica and the carbonates of lime, magnesia, and iron, which takes place at no very elevated temperature, in the presence of water, producing silicates of these bases with evolution of carbonic acid, enables us to understand the process which has given rise to the pyroxenes, serpentines, and talcs of this formation, while the argillaceous limestones, which are not wanting, contain all the elements of the garnet-rock.

The general conclusion deduced from these inquiries, and sustained by a great number of analyses, which I hope soon to submit to the Society, is, that the metamorphism of these Silurian strata has resulted from the chemical reaction, in the presence of water, of the elements existing in the original sedimentary deposits.